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Functional smiles: Tools for love, sympathy, and war

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Abstract (up to 150 words)

The smile is the most frequent facial expression, but not all smiles are equal. A social functional account holds that smiles of *reward*, *affiliation*, and *dominance* resolve basic social tasks, including rewarding behavior, social bonding, and hierarchy negotiation. Here we explore facial expression patterns associated with the three smiles. We modeled the expressions using a data-driven approach and showed that reward smiles are symmetrical and accompanied by eyebrow raising, affiliative smiles involve lip pressing, and asymmetrical dominance smiles contain nose wrinkling and upper lip raising. A Bayesian classifier analysis and a detection task revealed that the three smile types are highly distinct facial expressions. Finally, social judgments made by a separate participant group showed that the different smile type models convey different social messages. Our results provide the first detailed description of the physical form and social messages conveyed by the three functional smiles, documenting the versatility of these facial expressions.

Keywords: *facial expressions, emotion, smile, reverse correlation, social perception*

Everyone knows what a smiley face means. But real smiles are another story, and not always a happy one. Similar to a little black dress or a classic suit, smiles are a perfect fit for many social occasions, ranging from reuniting with a best friend to seeing a decapitated rat (Landis, 1924). Although people smile when they feel positive emotions (Ekman, 1973), they also do when they are miserable (Ekman, 2009), uncomfortable (Woodzicka & LaFrance, 2001), and embarrassed (Keltner, 1995). Indeed, facial expressions involving the contraction of the *zygomaticus major* muscle (Lip Corner Puller or Action Unit (AU) 12, Ekman & Friesen, 1978) constitute a single category – the smile – but could have different phylogenetic roots, as is reflected in animal ethology. For example, chimpanzees and canids retract the lip corners in functionally distinct facial expressions that appear during play, but also when communicating submission or threat (Fox, 1970; Parr & Waller, 2006).

Based on observations of both animal and human behavior, the Simulation of Smiles model (SIMS, Niedenthal, Mermillod, Maringer, & Hess, 2010) proposes at least three subtypes of smile, each defined by its role in the resolution of major adaptive problems of social living (Keltner & Gross, 1999). Specifically, these are reward smiles displayed to reward the self or others and communicate positive experiences or intentions; affiliative smiles to signal appeasement, and create and maintain social bonds; and dominance smiles to negotiate status within and across social hierarchies. In theory, reward smiles are displayed during positive sensory and social experiences, and thus are accompanied by and can reinforce pleasurable sensations through afferent feedback. Perceiving a reward smile can also elicit positive feelings through facial mimicry (Niedenthal et al., 2010). Reward smiles – which correspond to enjoyment smiles

described in the literature (Ekman, Davidson, & Friesen, 1990) – may have evolved from the play face of primates and canids (Fox, 1970; Parr & Waller, 2006). Based on previous findings, reward smiles should involve smooth and symmetrical action of the *zygomaticus major* muscle (i.e., Lip Corner Puller – AU12) and possibly be accompanied by eye constriction (i.e. Cheek Raiser – AU6, Frank & Ekman, 1993). Affiliative smiles facilitate social bonding by communicating approachability, acknowledgement, and appeasement (Eibl-Eibesfeldt, 1972; Ekman, 2009; Keltner, 1995), and thus may be functionally similar to the silent bared-teeth display in chimpanzees occurring during grooming, sexual solicitation, and submission (de Waal, 2003; Parr & Waller, 2006). Finally, dominance smiles serve to maintain and negotiate social or moral status, and are associated with superiority or pride (Senior, Phillips, Barnes, & David, 1999, Tracy & Robins, 2008), defiance (Darwin, 1999/1872), derision, and contempt (Ekman, 2009; Ekman & Friesen, 1986). Unlike reward and affiliative smiles, dominance smiles are assumed to elicit negative feelings in observers (Boksem, Smolders, & De Cremer, 2009; Davidson, Ekman, Saron, Senulis, & Friesen, 1990). Although no homologous primate facial expression is known, some facial expressions displayed by high-status animal aggressors involve smile components (Parr & Waller, 2006; Parr, Waller, & Vick, 2007).

While comparative studies and theoretical developments provide some insight into how smiles communicate reward, affiliation and dominance, their exact facial expression patterns remain unknown. Here, we use a data-driven approach to mathematically model the dynamic facial expression patterns (henceforth called *models*) communicating each smile type to individual observers (Study 1). We hypothesize that since the three smile types serve different social functions, each should be conveyed

using a specific facial expression pattern. We then test the extent to which the physical similarities and differences between smile models predict participants' responses in a verification task (Study 2). Finally, we predict that models of reward, affiliative, and dominance smiles reliably communicate related social motives, namely positive feelings, social connectedness, and superiority, respectively, and we test this hypothesis in the final experiment (Study 3).

In Study 1, we mathematically modeled the dynamic facial expression patterns of three smile types using a data-driven approach combining a dynamic facial expression generator (Yu et al., 2012) with reverse correlation (Ahumada & Lovell, 1971) and subjective human perception (e.g., Jack et al., 2014). Briefly stated, each participant observed a large sample of random facial animations that included bilateral and unilateral Lip Corner Puller (AU12) – a main component of smiling – and rated the extent to which each animation represented a reward, affiliative, or dominance smile (e.g., reward, very strong). Using these responses, we computed statistically robust dynamic models of each smile type for each participant, and then analyzed the resulting facial expression patterns.

Study 1. Construction of Dynamic Smile Models

Method

In the following sections, we report all measures and manipulations including any data exclusions. In all three experiments, we sought to maximize statistical power and to recruit as many participants as possible within approximately 3 weeks (with a minimum of 30 participants per study/cell). The Institutional Review Board at the University of Wisconsin-Madison approved all studies.

Participants. Fifty-five students (USA, 32 female, age $M = 18.76$ years, $SD = 0.79$) participated in exchange for course credit. We excluded data from 12 participants (8 female): 9 did not complete the experiment, 1 did not follow the instructions, and 2 African American participants, as their recognition performance could be impaired for white Caucasian faces used as stimuli (Elfenbein & Ambady, 2002). All participants had normal or corrected-to-normal vision.

Stimuli. Stimuli comprised 2,400 random facial animations, created using a Generative Face Grammar platform (GFG, Yu et al., 2012) and a 3D Morphable Model (3DMM, Blanz & Vetter, 1999). Figure 1 (Stimulus) illustrates the stimulus generation procedure. On each one of 2,400 experimental trials, the GFG randomly selected either bilateral Lip Corner Puller (AU12), Lip Corner Puller Left (AU12L), or Lip Corner Puller Right (AU12R) – e.g., in the example trial shown in Figure 1, Lip Corner Puller Left (AU12L, in red) – plus a random sample of between 1 and 4 other AUs (e.g., in Figure 1, Nose Wrinkler – AU9 in blue, and Upper Lip Raiser – AU10, in green) selected from a core set of 36 AUs. For each AU separately, a random movement is assigned by randomly selected values specifying each of 6 temporal parameters: onset latency, acceleration, peak amplitude, peak latency, deceleration and offset latency (see labels illustrating the red curve Figure 1). We used a cubic Hermite spline interpolation (5 control points, 30 time frames, 24 frames per second) to generate the time course of each AU. We then presented the random facial animation on one of eight white Caucasian face identities (4 female, age $M = 23.0$ years, $SD = 4.1$) captured under the same conditions of illumination (2600 lux) and recording distance (143 cm; Dimensional Imaging; see Yu et

al., 2012). All animations started and ended with a neutral expression, and had the same duration of 1.25s.

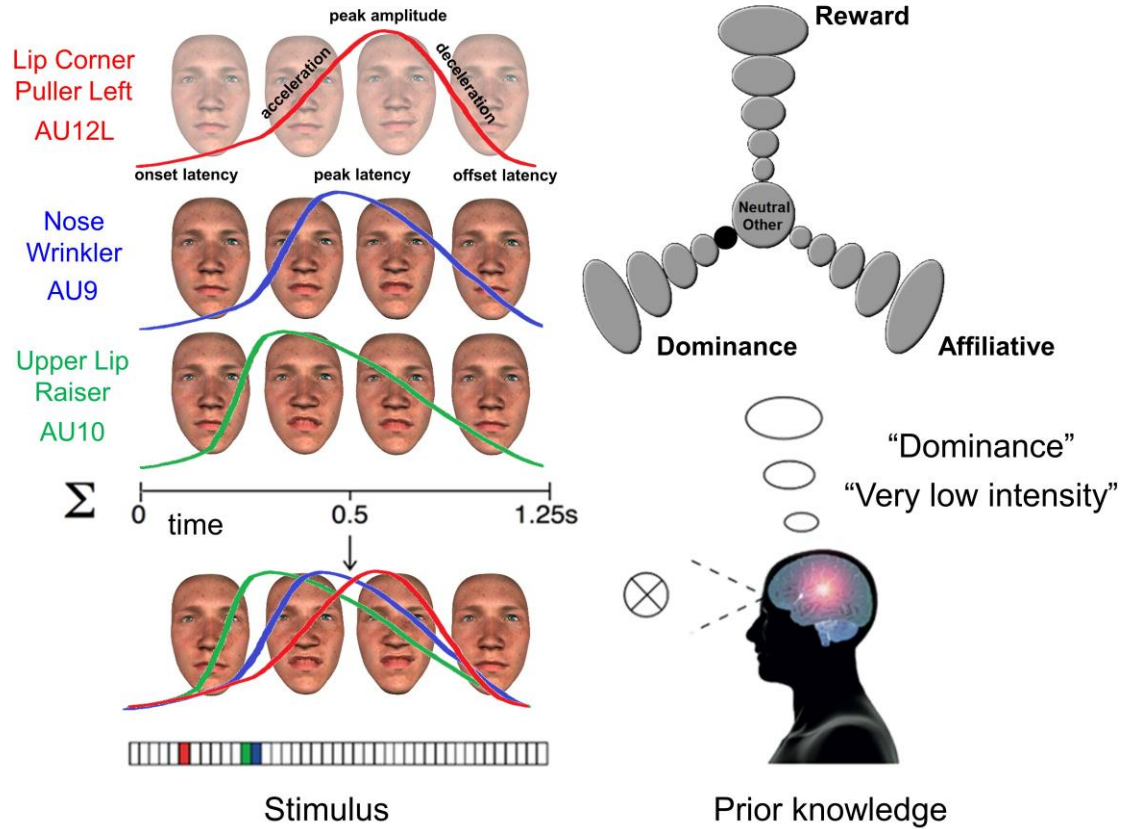


Fig. 1. Modelling dynamic facial expression patterns of three smile types. *Stimulus.* On each experimental trial, the Generative Face Grammar (GFG, Yu et al., 2012) selected a core smile face movement – here, Lip Corner Puller Left, Action Unit (AU) 12, color-coded in red – and a random subset of other AUs (here, Nose Wrinkler – AU9 color-coded in blue, Upper Lip Raiser – AU10 color-coded in green). For each individual AU selected, the GFG assigned a random movement by randomly selecting values for 6 temporal parameters (see labels illustrating the red curve), and combines these dynamic AUs to produce a random photorealistic facial animation, illustrated here with four

snapshots across time. The color-coded vector at the bottom represents the 3 randomly selected AUs comprising the stimulus on this trial. **Prior Knowledge.** On each trial, participants categorized the random facial animation according to degree to which is represented one of three smile types – i.e., ‘reward’, ‘affiliative,’ and ‘dominance’ (e.g., here, ‘dominance,’ ‘very low,’ see black circle) when the facial movement pattern corresponded with their prior knowledge of that smile type. Otherwise, if the facial expression patterns did not correspond to any of the listed labels, they selected ‘Neutral/Other.’ Each participant categorized 2,400 such face facial animations displayed on same-race faces. Using established model fitting procedures (see *Model Fitting*), we thus computed a total of 129 dynamic smile models (43 participants x 3 smile types). Figure 2A shows a summary of the resulting facial expression models for each smile type where color-coded face maps show the proportion of individual models comprising each AU (see colorbar on left; see also *Supplemental Online Materials, S1, Table S1c* for the number and proportion of models with each AU). The same AU patterns are displayed on a face identity below.

Procedure. Figure 1 (Prior Knowledge) illustrates the task procedure. On each experimental trial, the participant viewed the randomly generated stimulus and categorized it according to the degree to which it represented one of three smile types – i.e., ‘reward’, ‘affiliative,’ and ‘dominance’ (e.g., here, ‘dominance,’ ‘very low,’ see black circle in Figure 1) using a modified Geneva Emotion Wheel scale (GEW, see Scherer, Shuman, Fontaine, & Soriano, 2013). Participants categorized the stimulus as such when the facial movement pattern corresponded to their prior knowledge of that

smile type. Alternatively, if none of the labels accurately described the facial animation, participants selected 'Neutral/Other.' In other words, even though all animations involved Lip Corner Puller – a core component of smiling – participants were not constrained to categorize any of the facial animations as a smile. Each participant categorized 2,400 such random facial animations completed over 12 x 20 minute blocks within a week. Each stimulus (size: 600 x 800 pixels, approximately 10 x 15 cm) appeared in the center of the screen on a black background for 1.25s and played only once. Stimuli subtended approximately 14.71° (vertical) and 9.61° (horizontal) of visual angle maintained using a viewing distance of approximately 53 cm.

Prior to the experiment, participants read definitions of the three social functions of the smiles. Consistent with the Simulation of Smiles Model (Niedenthal et al., 2010), we described reward smiles as reflecting a happy response, affiliative smiles as reflecting positive social intentions, and dominance smiles as reflecting superiority. For each smile type, we provided two examples of social situations in which a person would make such a smile: for the reward smile – 'A person learns that he/she just got hired for his/her dream job'; for the affiliative smile – 'A person thanks someone for their help in a store'; for the dominance smile – 'A person crosses paths with an enemy after winning an important prize.' Participants completed the first block in a laboratory with a female experimenter present only while accessing the experimental website and reading the instructions. Participants completed the remaining blocks independently, outside of the laboratory and on their personal computers. We instructed participants to take a minimum 3 hour break in-between blocks, and to complete the experiment without distractions.

Model fitting

Following the experiment, we used each participant's behavioral responses and dynamic AU patterns shown on each trial to mathematically model – independently for each participant – the dynamic facial expression patterns associated with each smile type. Specifically, for every participant we computed the relationship between the dynamic AUs presented on each trial and the participant's behavioral responses (e.g., 'rewards, very high') to identify the AUs that are significantly correlated with each smile type for that participant. To do this, we computed a Pearson correlation between the binary vector detailing the presence vs. absence of each AU on each trial and the corresponding binary vectors detailing the response of the participant. We thus assigned a value of 1 to all significant correlations ($p < 0.05$) and 0 otherwise, thus producing a 1 X 36-dimensional binary vector detailing the composition of AUs significantly correlated with each smile type for each participant. We modeled the 6 temporal parameters of each active AU as a linear function of response intensity for each facial expression. We estimated linear slope and offset using least squares regression. For visualization purposes, we evaluated the model at three equally spaced points spanning the full intensity range and passed the resulting three sets of temporal parameters to the animation system along with the significantly correlated AUs. Figure 2a shows the resulting facial expression models displayed as color-coded face maps and on a face identity, along with a list of significant AUs.

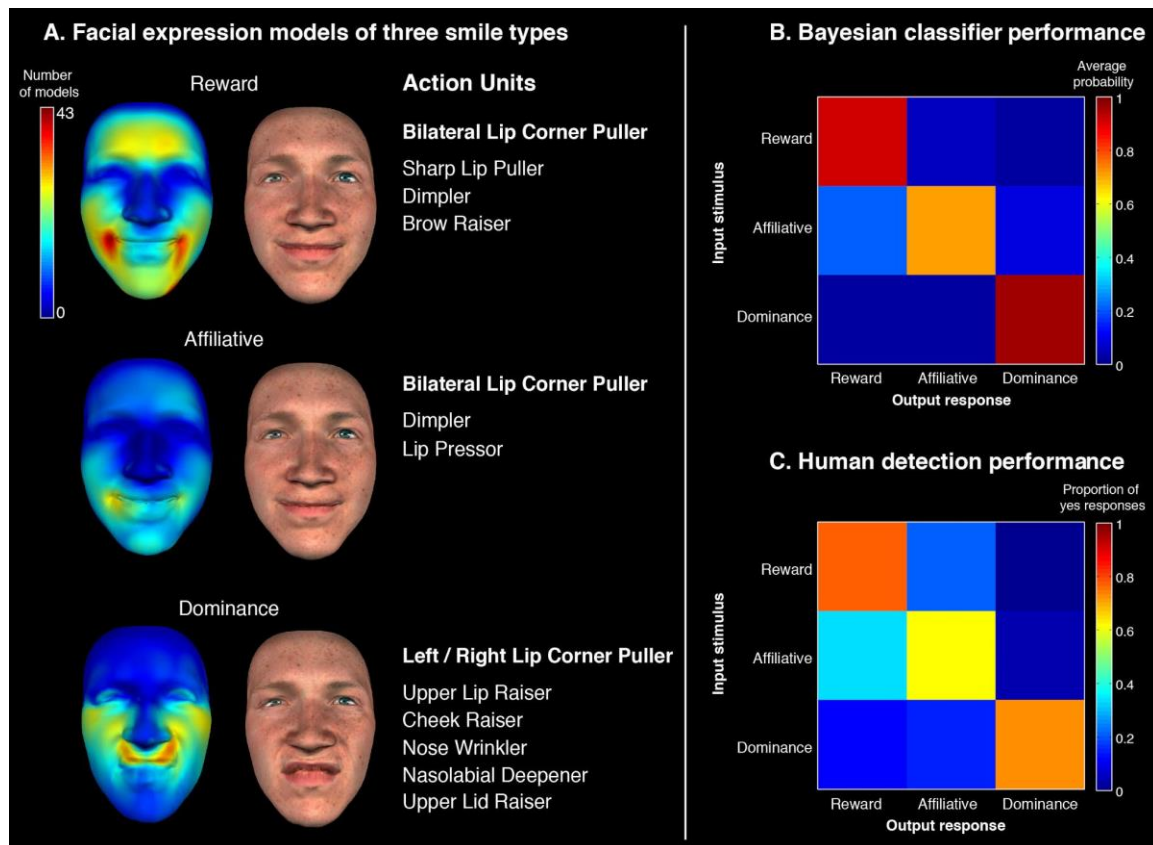


Fig. 2. Facial expression patterns of the three smile types with Bayesian classifier and human detection performances. **A. *Facial expression models of three smile types.*** Color-coded face maps show for each smile type – ‘reward,’ ‘affiliative,’ and ‘dominance’ – the Action Units (AUs) that are shared across individual participant models (red indicates a high number of models, maximum = 43 models, see colorbar to left). The same facial expression patterns are also displayed on a face identity to the right. The AUs listed next to each face appear in at least 17 of the models. As shown by the colored face maps and lists of AUs, each smile type is represented using a specific facial expression pattern. For example, reward smiles involve Brow Raiser (AU1-2), affiliative smiles involve Lip Pressor (AU24), and dominance smiles involve Upper Lip Raiser (AU10) and Nose Wrinkler (AU9). Reward and affiliative smiles both show symmetrical (i.e., bilateral) the

Lip Corner Puller (AU12), whereas dominance smiles show asymmetrical Lip Corner Puller (i.e., either left or right, AU12L/R). **B. Bayesian classifier performance.** To objectively examine the distinctiveness of the facial expression patterns of each smile type, we used a Bayesian classifier approach with a 10-fold cross validation procedure. The color-coded matrix shows the average probability of each smile type classification for every smile type. Red indicates high probability and blue indicates low probability (see color bar to right). Diagonal squares show high classification accuracy for each smile. Only affiliative smiles elicited significantly lower accuracy than dominance smiles ($p < 0.05$) and were misclassified significantly more as reward than other smiles ($p < 0.05$). **C. Human detection performance.** The color-coded matrix shows the performance of human observers in detecting each smile type from the smile models. Color-coded squares show for each smile type (input stimulus), the proportion of yes responses (pooled across observers) associated with each set of smile models (output response). Red indicates high proportions and blue indicates low proportions of responses (see color bar to right). Diagonal squares (i.e., hits) show that each smile type is detected with high accuracy, with lower detection sensitivity for affiliative smiles ($M_d = 0.38$) than dominance smiles ($M_d = 0.77$, $p < 0.05$). Off diagonal squares (i.e., false alarms) show that when detecting affiliative smiles, participants tended to respond yes to reward smile models (see centre-left cyan square).

As shown by the colored face maps and lists of AUs, each smile type is associated with a specific facial expression pattern. Specifically, reward smiles involve the symmetrical Lip Corner Puller (AU12), Sharp Lip Puller (AU13), Dimpler (AU14), and

Brow Raiser (AU1-2); affiliative smiles also comprise symmetrical Lip Corner Puller (AU12) but are accompanied by Dimpler (AU14) and Lip Pressor (AU24). Finally, dominance smiles involve the asymmetrical Lip Corner Puller (i.e., AU12L, or AU12R), Upper Lip Raiser (AU10), Cheek Raiser (AU6), Nose Wrinkler (AU9), Nasolabial Deepened Left (AU11L) and Upper Lid Raiser (AU5).

To objectively examine the distinctiveness of the facial expression patterns of each smile type, we used a multinomial Naïve Bayesian classifier approach with a 10-fold cross validation procedure (Kohavi, 1995). Specifically, we split the facial expression patterns (i.e., AU patterns represented as 1 X 36 binary vectors) into 10 disjoint subsets (i.e., folds) and, using 9 of the 10 subsets, trained a classifier to associate the smile type patterns with their smile type labels (i.e., reward, affiliative, or dominance). Following training, we tested the classifier using the remaining set of facial expression patterns. Each test therefore produced a performance score for each of the three smile types. We repeated this training and testing procedure 10 times to ensure that each set had been tested. We then computed for each smile type the average probabilities of classifying the smile pattern with each smile type label – e.g., the probability that a reward smile would be classified as reward, affiliative, or dominance. Figure 2b shows the results as a color-coded matrix where red indicates high probability and blue indicates low probability of a given smile type classification (see color bar to right). As shown by the diagonal squares, the smile models of each smile type were classified with high accuracy and significantly above chance ($p < 0.05$) as determined by a binomial proportion test. Pairwise binomial proportion tests between the three smile types revealed that affiliative smiles elicited significantly lower accuracy ($p < 0.05$) than dominance

smiles. An examination of the distribution of errors for affiliative smiles (see off diagonal squares) showed that this lower performance is due to significant misclassifications as reward smiles (in 21.4% of observations, $p < 0.05$) as determined by binomial proportion tests. See *Supplemental Online Materials, S1, Table S1d* for all probabilities).

Study 2. Detection of Smile Types

Such specificities in the facial expression patterns and the Bayesian classifier performance suggest that people should accurately detect all three smile types with affiliative smiles being harder to classify than reward or dominance smiles. To explore observers' sensitivity to the functional smiles, we recruited new participants who completed a verification task using the dynamic facial expression models derived in Study 1.

Method

Participants. One hundred and seven white Caucasian students (USA, 71 female, age $M = 19.55$ years, $SD = 1.59$) participated in exchange for course credits. We excluded data from three participants (2 female) because they deviated from the experimental instructions. All participants had normal or corrected-to-normal vision.

Stimuli. We displayed every dynamic smile model derived in Study 1 on four different white Caucasian face identities (2 female, age $M = 21.5$ years, $SD = 6.46$), resulting in a total of 2,580 stimuli (3 smiles X 5 intensities X 43 participants X 4 identities).

Procedure. Prior to the task, we told participants that they would see a large number of animated facial expressions. On each trial, participants viewed a facial animation followed by one of three labels – ‘reward smile,’ ‘affiliative smile,’ or ‘dominance smile.’ We instructed participants to select ‘yes’ if the label accurately described the facial animation, and ‘no’ if it did not. Participants viewed 300 stimuli (100 per smile type) selected pseudo-randomly with replacement from the pool of 2,580 stimuli and presented in random order across the experiment. Among the 100 trials asking about a given smile type, 50 displayed models of the target smile, and the other 50 – equal numbers of the two other smile types - presented as distractors. Participants remained naïve to the proportion of targets and distractors throughout the experiment. We displayed each facial animation on a black background in the center of the screen, and played once for 1.25s. Stimuli subtended 14.71° (vertical) and 9.61° (horizontal) of visual angle with a chin rest maintaining a constant viewing distance of 51cm. We used an online interface to display the stimuli and record participant responses. We tested participants on individual computer stations, and used the same smile-type definitions as in Study 1.

Results

To examine whether human observers can accurately detect the different smile types in the dynamic facial expression models, we computed d-prime – a measure of signal detection sensitivity (Green & Swets, 1966) – for each of the three smile types by pooling the responses from all participants. A one-way ANOVA applied to the resulting d-prime values showed that detection sensitivity varied significantly across the smile types [$F(2, 206) = 24.08$; $p < .001$] with reward smiles detected with the highest accuracy ($M_d = 0.81$,

$SD_{d'} = 0.24$), followed by dominance ($M_{d'} = 0.77$, $SD_{d'} = 0.86$), and then affiliative smiles ($M_{d'} = 0.38$, $SD_{d'} = 0.22$). Figure 2c illustrates the results. Color-coded squares show for each smile type (the input stimulus) the proportion of yes responses associated with each set of smile models (the output response) where red indicates a high proportion of yes responses and blue indicates a low proportion (see color bar to right). Diagonal squares (i.e., hits) show that each smile type is detected with high accuracy. While reward and dominance smiles elicited similar detection performance ($p > 0.05$), participants' sensitivity to the affiliative smiles was significantly lower, $ps < 0.05$. Further analysis of participant responses showed that the significantly lower detection sensitivity for affiliative smiles was due to a large number of false alarms ($M_{FA'} = 0.21$ compared to $M_{FA'} = 0.08$ and $M_{FA'} = 0.14$ for reward and dominance smiles, respectively). The off diagonal squares (i.e., false alarms) reveal confusions between affiliative and reward smiles. Specifically, when asked to detect affiliative smile (input stimulus), participants responded positively to reward smile models (output response, see center-left cyan square) significantly more than to dominance smile models (see centre-right blue square, $t(84) = 20.15$, $p < .001$). See *Supplemental Online Materials, S2, Tables S2a and S2b* for detection statistics for each individual model and proportions of positive responses.

The human pattern of performance closely mirrors that of the Bayesian classifier (see Figure 2b). In accordance with the objective analysis of the AU patterns, showing physical similarities between reward and affiliative smiles, participants could clearly distinguish dominance smiles from reward and affiliative smiles, whereas the latter two smile types elicited some similarity in perceptual judgments. In the next study we examined observers' judgements of social motives conveyed by the three smile models.

Consistently with the present findings, we predicted that reward and affiliative smiles, given their perceptual similarity, should convey similar messages of positive feelings and social connection. On the other hand, dominance smiles should elicit clearly different judgements and be associated with superiority rather than with positive and prosocial motives.

Study 3. Social Information Communicated by Smile Type

In line with proposing that smiles of reward, affiliation, and dominance comprise distinct facial movements to serve different social functions, the SIMS model also proposes that these smiles convey different social messages – i.e., positive feelings, social connectedness, and superiority, respectively. To test this hypothesis, we recruited a new set of participants who rated the feelings and social motives communicated by a subsample of the smile models.

Method

Participants. Sixty-two students (USA, 41 female, age $M = 19.17$ years, $SD = 2.11$) participated in exchange for course credit. Since we displayed the smile models on white Caucasian faces, we discarded data from one Arab American female. All participants had normal or corrected-to-normal vision.

Stimuli. From all the facial expression models tested in Study 2, we pseudo-randomly selected, for each smile type, five models with significantly high d' -prime values (reward: $M_{d'}=0.89$, $SD_{d'}=0.15$, $Z_{d'}=1.36$; affiliative: $M_{d'}=1.44$, $SD_{d'}=0.17$, $Z_{d'}=1.29$; dominance: $M_{d'}=2.79$, $SD_{d'}=0.09$, $Z_{d'}=0.76$), see *Supplemental Online*

Materials, S2, Table S2. We displayed each dynamic facial expression model on eight new white Caucasian face identities (4 male, age $M = 23.5$ years) and from these created two sets of stimuli each comprising 60 stimuli (3 smile types X 5 models X 4 identities; 2 male, version 1: age $M = 26.75$ years, $SD = 5.91$ years, version 2: age $M = 20.25$, $SD = 3.30$ years).

Procedure. On each experimental trial, participants viewed a facial expression stimulus presented along with one of three questions – ‘To what extent is this person (1) having a positive feeling or reaction to something/someone?’ (2) ‘feeling a social connection with someone?’ or (3) ‘feeling superior or dominant?’ Participants responded on every trial using a 7-point Likert scale ranging from ‘not at all’ to ‘very much.’ We presented facial expression stimuli in the center of the screen on a black background, with the question below the facial expression in white text. Facial expression stimuli subtended approximately 14.71° (vertical) and 9.61° (horizontal) of visual angle with participants instructed to maintain a viewing distance of 51 cm. Each stimulus played for 1.25s and participants could replay the video as many times as desired. We displayed each facial expression model three times across the experiment paired with a different question each time. Therefore, each participant completed a total of 180 trials (5 models X 3 smile types X 4 identities X 3 questions). We randomized the order of trials across the experiment for every participant. Subjects were tested in a laboratory and worked at individual computer stations. We used an online interface created in Qualtrics to display the stimuli and collect responses (version 1.869s, Provo, UT).

Results

To examine whether different smile types communicate specific feelings and social motives, we analyzed the participant ratings of each smile type according to the three questions posed in the experiment. Specifically, we computed for each smile and for each of the three questions, the proportion of responses distributed across the 7 different rating levels ('not at all' to 'very high') using data pooled across participants. Figure 3 shows the results. The color-coded matrix shows the proportion of responses assigned to each rating level for each question where red indicates a high proportion of responses and blue indicates a low proportion (see colorbar to right). As shown by the orange and yellow squares, both reward and affiliative smiles consistently elicited high ratings of positive feelings, social connection, with more inconsistent ratings of superiority as shown by the flatter distribution of responses across the different levels. In contrast, as shown by the red squares, dominance smiles consistently elicited high ratings of superiority and generally low ratings of positive feelings and social connectedness.

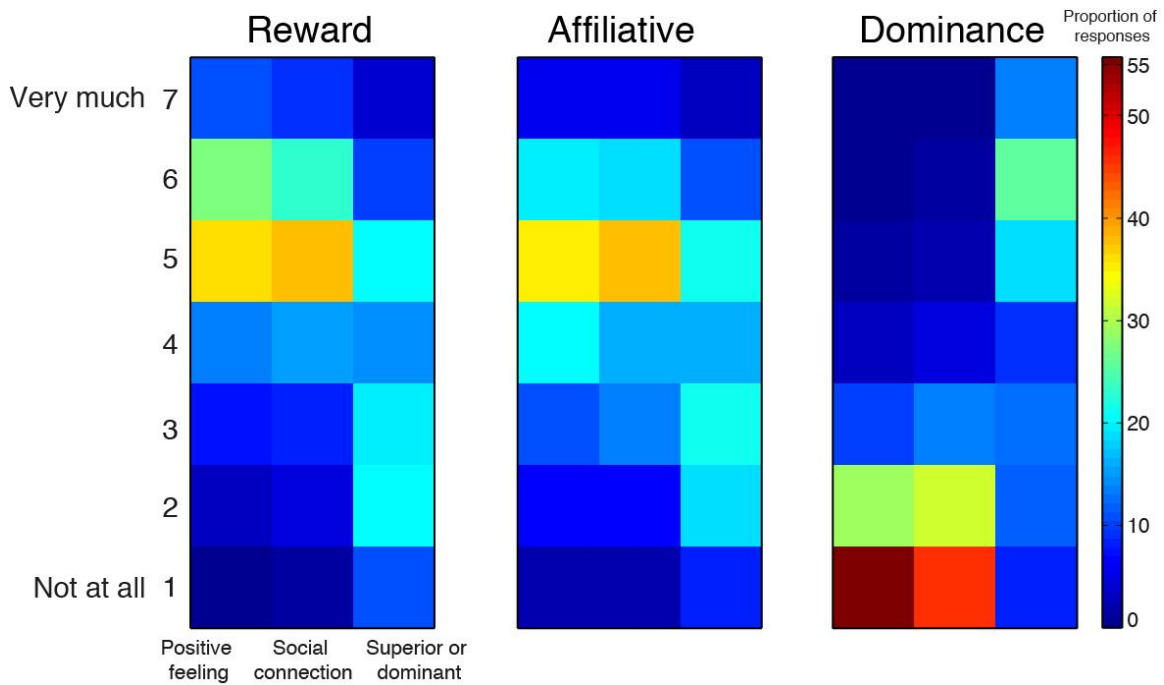


Fig. 3. Distribution of responses across ratings for each social motive and smile type.

Each color-coded matrix shows the proportion of participants' responses distributed across the 7 rating levels ('not at all' to 'very much') for the feelings and social motives communicated by the smile models. Red squares indicate a high proportion of responses with blue squares indicating low proportions (see color bar to right). Observers judged reward and affiliative smiles as high in positive feelings and social connection with low ratings for superiority. Dominance smiles consistently elicited low ratings for positive feelings and social connectedness and generally high ratings for superiority.

To explore how participants' ratings of reward, affiliative, and dominance smiles varied as a function of social motives, we used a linear mixed model analysis according to the

established procedures (Barr, Levy, Scheepers, & Tily, 2013)¹ and regressed participants' ratings on two planned orthogonal contrasts². We detail the predictions and results of each smile type below. First, we predicted that reward smiles would be rated significantly higher on positive feelings and social connection than feelings of superiority or dominance. Second, that reward smiles would be rated significantly higher on positive feelings than on social connection. In line with our first prediction, reward smiles elicited significantly higher ratings of positive feelings ($M=5.08$, $SD=0.74$) and social connectedness ($M=4.91$, $SD=0.76$) compared to feelings of superiority ($M=3.59$, $SD=1.18$); $b=-.46$, $SE=0.07$, $t(37.02)=-6.44$, $p < .001$). Consistently with the second prediction, reward smiles elicited higher ratings of positive feelings than of social connectedness ($b=0.08$, $SE=0.02$, $t(6.95)=3.40$, $p=.01$).

We applied the same contrasts to test ratings of social motives of affiliative smiles. Results showed that affiliative smiles elicited higher ratings of social connection ($M=4.57$, $SD=0.80$) and positive feelings ($M=4.61$, $SD=0.76$) than superiority ($M=3.67$, $SD=1.00$); $b=-0.31$, $SE=0.07$, $t(23.29)=-4.18$, $p < .001$. However, our second prediction was not supported, such that affiliative smiles did not differ in their ratings of social connectedness and positive feelings ($b=0.01$, $SE=0.02$, $t(6.80)=0.63$, $p=.55$).

Finally, for dominance smiles, we predicted higher ratings of superiority compared to ratings of positive feelings and social connectedness, which was supported by the data ($b=0.90$, $SE=0.07$, $t(61.92)=12.10$, $p < .001$; superiority: $M=4.49$, $SD=1.50$, positive

¹ All regression models included a by-subject random intercept, a by-subject random slope, a by-item (identity) random intercept, and a by-item random slope.

² Contrast 1: positive emotions: -1, social connection: -1, superiority: 2; Contrast 2: positive feelings: 1, social connection: -1, superiority: 0.

feelings: $M=1.69$, $SD=0.64$, social connection: $M=1.89$, $SD=0.71$)³. We performed all statistical analyses using RStudio version 0.96 (RStudio, Inc.) and SPSS version 20.0 for Windows (SPSS Inc., Chicago, IL).

General Discussion

Here, we aimed to characterize and compare the specific movements conveying reward, affiliative, and dominance smiles. We modeled these facial expression patterns using a dynamic facial expression generator, the method of reverse correlation, and subjective perception. Analysis of the resulting facial expression models (43 participants X 3 smile types) showed that the three smiles are represented by specific movements. Specifically, reward smiles involve eyebrow flashes (i.e., the Inner-Outer Brow Raiser – AU1-2), Sharp Lip Puller (AU13), and Dimpler (AU14); affiliative smiles involve Lip Pressor (AU24) and Dimpler (AU14); dominance smiles comprise Upper Lid Raiser (AU5), Nose Wrinkler (AU9), Cheek Raiser (AU6), and Upper Lip Raiser (AU10). For each smile type, these AUs accompanied a core component of smiling – Lip Corner Puller (AU12), the *zygomaticus major* muscle. While reward and affiliative smiles both involve symmetrical movements of Lip Corner Puller (AU12), dominance smiles are asymmetrical and comprise either unilateral Lip Corner Puller Right (AU12R) or Left (AU12L). As predicted by the distinctiveness of the facial expression patterns of the three smile types, both a Bayesian classifier and a set of human participants could accurately discriminate and detect each of them. Finally, in line with predictions from the SIMS model, each smile type communicated a specific set of broader social messages – i.e.,

³ The second contrast (contrast 2: 1, -1, 0), testing the residual within-group variance, was also significant ($b=-0.10$, $SE=0.04$, $t(9.47)=-2.82$, $p=.02$).

reward and affiliative smiles elicited high ratings of positive feelings and social connection, and generally low ratings of superiority, whereas dominance smiles yielded an opposite pattern of results.

Our results suggest a relationship between the form and function of each of the three smile types that supports existing theories of smiles and non-verbal communication more broadly. Specifically, our analyses revealed distinct AU patterns for each smile type, which are commensurate with their specific social functions. For example, reward smiles involve face movements that increase sensory exposure (Inner-Outer Brow Raiser – AU1-2, which could indicate the desire to prolong sensory input and feelings of pleasure (Niedenthal et al., 2010; Susskind et al., 2008). Affiliative smiles contain the Lip Pressor (AU24), which covers the teeth and thus could indicate approachability via the absence of aggression (Darwin, 1999/1872; Zumbroich, 2009). Similarly, dominance smiles involve Nose Wrinkler (AU9) and Upper Lip Raiser (AU10), associated with facial expressions of disgust, anger, and sensory rejection (Chapman et al., 2009; Darwin, 1999/1872; Ekman & Friesen, 1978; Jack, Garrod, & Schyns, 2014), suggesting fundamental similarities in communicating rejection, negativity (Niedenthal et al., 2010), low affiliation, and high superiority (Knutson, 1996). Dominance smiles also contain the Upper Lid Raiser (AU5) – i.e., the eye whites – typical of facial expressions of anger, fear, and surprise (Ekman & Friesen, 1978; Jack et al., 2016) and potentially communicating a broad social message of immediacy. Finally, dominance smiles also involve the Cheek Raiser (AU6), often associated with genuine enjoyment (e.g. Ekman et al., 1990). Our data thus support previous findings linking AU6 with facial expressions other than smiles – including those communicating negative affect such as distress,

despair, or disgust (Messinger, Mattson, Mahoor, & Cohn, 2012; Scherer & Ellgring, 2007). The involvement of eye constriction in the dominance smiles is also consistent with existing theories of contempt expression (Darwin 199/1872; Izard & Haynes, 1988).

We also show differences in the core component of smiles – the Lip Corner Puller (AU12) – across the three smile types. Specifically, reward and affiliative smiles, both conveying positive feelings and social connectedness, involve the symmetrical Lip Corner Puller – a face movement eliciting judgments of genuineness and approach motivation (Ekman, 2009; Schmidt & Cohn, 2001). In contrast, dominance smiles, which communicate negative feelings and superiority, involve asymmetrical Lip Corner Puller (AU12L or AU12R) – a movement associated with the related social concepts of contempt and derision (Darwin, 1999/1872; Ekman & Friesen, 1986). Given the potentially negative social consequences of dominance smiles, their similarity to disgust expressions, and the relatively weak visibility of the AU12 in our dominance models, one could object that such expressions are not instances of a smile category at all. We addressed this question in an additional study, for which we created new smile stimuli. Fifteen experienced actors encoded the smiles after being coached about appearance of the smiles as indicated by the present findings (see *Supplemental Online Materials, S3* and Figure 4 for details; Martin, Abercrombie, Gilboa-Schechtman, & Niedenthal, 2017). Participants ($N = 73$) saw still images of reward, affiliative, and dominance, in addition to other expressions, and categorized them as smiles using a yes/no response format. Results showed that participants were significantly more likely than chance to categorize reward, affiliative, and dominance smiles as smiles (estimated probabilities: 98%, 86%, and 69%, respectively). Neutral and disgust facial expressions were not categorized as smiles

(estimated probabilities: 6%, 2%). Our results reveal the facial movements involved in the three smile categories but also indicate that similarities in the underlying feelings and social motives translate into a greater similarity in facial expression patterns. Namely, the SIMS model describes reward and affiliative smiles as related in that they both convey generally positive feelings and motives, which – according to biological signaling accounts – should be communicated using similar signals (Hasson, 1997, Smith et al., 2005). While we found some specificity in the reward and affiliative smiles, both contained symmetrical Lip Corner Puller. Consistently, they were sometimes confounded by human participants (see Figure 2) and both conveyed similar feelings and social motives (see Figure 3). It is important to note that we explored smile categories that might be used for social living, but for which semantic concepts are not easily accessible – which could reduce participants' ability to explicitly use the labels of reward, affiliative, and dominance smiles. A further test of the distinction between the proposed functions of smiles could include the assessment of implicit physiological, neuroendocrine, and behavioral responses (Martin et al., 2017). Paradigms involving social situations, such as trust games or providing performance feedback can also provide a more precise understanding of the social impact the three functional smiles (Martin et al., 2017; Rychlowska, van der Schalk, Martin, Niedenthal, & Manstead, 2017).

Here, we showed that participants associated specific and distinct facial expression patterns with reward, affiliative, and dominance smiles, which also communicated positive feelings, social connectedness, and superiority, respectively. Our results converge with the findings of a recent study (Rychlowska et al., 2015), which revealed that respondents from nine countries in North America, Europe, and Asia divide

the social functions of smiles in three categories consistent with the theoretical distinctions proposed in the SIMS model.



Fig. 4. Reward, affiliative, and dominance smile images (frames taken from a movie) based on the present findings and used in Martin et al. (2017). Dominance smiles (right column) involve lower activations of bilateral Lip Corner Puller (AU12) and higher levels of Nose Wrinkler (AU9) than reward smiles (left column). Observers preferentially categorized all three expressions as smiles rather than non-smiles (*Supplemental Online Materials, S3*; Martin et al., 2017).

We anticipate that our precise characterization of the facial expression patterns of reward, affiliative, and dominance smiles, and the social messages they communicate will contribute to furthering knowledge of the social function and form of these facial expressions. Smile models generated in the present studies as well as video recordings of these smiles (Martin et al., 2017) could for example serve as a framework for the automatic detection and classification of smiles that occur in real life situations, such as those displayed during presidential elections or interactions with intimate others (Kunz, Prkachin, & Lautenbacher, 2013) using computer vision algorithms. Finally, further analysis of the temporal dynamics of different smile types has the potential to inform the clinical assessment of the surgeries aimed at the reanimation of the smile (Manktelow, Tomat, Zuker, & Chang, 2006; Tomat & Manktelow, 2005).

Together, our results highlight the versatile nature of the human smile, which can be used for multiple social tasks including “love, sympathy, and war.”

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